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CONTROL OF THE SATIN MOTH BY SPRAYING IN ALTERNATE YEARS

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INTRODUCTION

The satin moth (*Stilpnotia salicis* L.) was first discovered in the United States in June, 1920. At that time it was found defoliating a number of Carolina poplar trees along the parkway near the Malden-Medford city line, a few miles from Boston, Mass. It has not been found possible to determine the original source of infestation or the time when this insect arrived in the United States, but it was undoubtedly present here a few years prior to 1920. It was first found in British Columbia in July, 1920, and in the State of Washington in 1922.

Since 1920 this insect has spread rapidly. Its known occurrence in New England on November 1, 1929, was as follows: In Maine, in the counties of York, Cumberland, Androscoggin, Sagadahoc, Lincoln, Knox, and Waldo, and parts of Oxford, Kennebec, Franklin, Somerset, Penobscot, and Hancock; in New Hampshire, in Rockingham, Strafford, Hillsboro, Merrimack, Belknap, and Cheshire Counties, and parts of Sullivan, Grafton, and Carroll Counties; in Vermont, in eight towns in the eastern part of the State, seven in Windham County, and one in Windsor County; in Massachusetts, in all counties with the exception of Berkshire. In Rhode Island it occurred in localities distributed through the entire State, and in Connecticut it was found in all towns east of the Connecticut River, and in two towns west of the river.

The most favored food plants of the satin moth in New England are the Lombardy poplar (*Populus nigra italica* DuRoi), Carolina poplar (*P. deltoides* Marsh.), balm-of-Gilead poplar (*P. balsamifera candicans* (Ait.) Gray), white poplar (*P. alba* L.), largetooth

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aspen (*P. grandidentata* Michx.), quaking aspen (*P. tremuloides* Michx.), and golden willow (*Salix alba*, var *vitellina* (L.) Koch).[1]

The most effective method of controlling this insect is spraying with lead arsenate powder in water, in the proportion of 5 pounds to 100 gallons of water, during the period when the caterpillars are feeding. In most of the cities and towns in Massachusetts, where the law of the State requires control work against the gipsy moth, and in many of the cities and larger towns of other New England States shade and roadside trees are sprayed regularly. This procedure against the gipsy moth is, incidentally, an important aid in the control of the satin moth.

In the winter of 1927–28, realizing that the satin moth was spreading rapidly and causing more damage to the foliage in a larger area each year, the senior writer became impressed with the idea that a reduction in the cost of controlling this insect might result from a modification of the spraying practices usually employed. Accordingly, a method of spraying consisting of a single application of a mixture of lead arsenate and fish oil in alternate years was suggested; whereupon it was decided to conduct experiments to test its practicability.

The junior writer, who has had considerable experience with power spraying and with adhesives for sprays of lead arsenate, was at that time studying methods for controlling the satin moth. He assumed responsibility for the experiments conducted in 1928 and 1929, and during those years carried out the plans in the field.

HABITS OF THE SATIN MOTH

The satin moth passes the winter as a third-stage larva beneath a small web which is usually constructed in crevices of the bark of a tree. In New England emergence from hibernation in the following spring begins late in April and continues through the greater part of May. The caterpillars begin feeding at once, and become fully grown about June 25. They then spin loose cocoons, in which they pupate, the adults issuing about 10 days later. The moths emerge during a period of about three weeks, beginning the first week in July.

After mating, egg laying begins. Hatching occurs about 15 days after deposition of the egg, and the young larvae shortly begin feeding on both sides of the leaf (fig. 1), on both the old and the new growth of tissue. Their feeding continues through the second stage, after which they construct their hibernating webs; when these are completed they molt to the third stage and then begin hibernation.

IMPROVEMENT IN SPRAYING OPERATIONS

In spraying operations against the gipsy moth, especially the work of suppression carried on by the Plant Quarantine and Control Administration, fish oil has for several years been used as an adhesive.[2] It causes the lead arsenate to adhere to the foliage for a considerable length of time. Before fish oil came into use it was a very difficult matter to make lead arsenate cling to such foliage as

[1] BURGESS, A. F., and CROSSMAN, S. S. THE SATIN MOTH, A RECENTLY INTRODUCED PEST. U. S. Dept. Agr. Bul. 1469, 23 p., illus. 1927.

[2] HOOD, C. E. FISH OIL AS AN ADHESIVE IN LEAD-ARSENATE SPRAYS. U. S. Dept. Agr. Tech. Bul. 111, 28 p., illus. 1929.

that of poplar and willow, or to cause it to adhere very long to average foliage, especially in wet seasons. With the use of fish oil this difficulty is not encountered.

In view of this fact, it occurred to the senior writer that, in the spraying operations against the satin moth, it might be possible, by spraying poplar trees with the mixture of lead arsenate and fish oil in May or early in June, to control the larvae of one generation, and because this spray remains on the foliage for the greater part of the summer, it might also be possible to control the small larvae of the next generation. Experiments were accordingly begun in 1928 and continued during 1929.

EXPERIMENTS IN 1928

In 1928 a number of poplar trees in various well-separated localities were selected for the experiments, most of the trees being heavily infested with the satin moth.

FIGURE 1.—Carolina poplar leaves fed upon by small larvae of the satin moth. ×½

On June 8, 1928, 10 large Carolina poplar trees in Nashua, N. H., were sprayed with a mixture of powdered lead arsenate and water in the proportion of 5 pounds of the arsenate to 100 gallons of water, with the addition of fish oil as an adhesive. Figure 2 shows several of these trees, photographed June 12, 1929. They were about 15 per cent defoliated at the time of spraying, and were rather heavily infested with the satin moth. A few large Carolina poplars near by were left as checks. On June 8, also, four Carolina poplar trees of medium to large size, in Derry, N. H., were sprayed with a mixture of powdered lead arsenate and water in the same proportion as that just given, with fish oil added as an adhesive, and one was left as a check. The infestation on these trees was medium to heavy, and they were about 10 per cent defoliated.

On June 15, 1928, four Carolina popular trees of medium size at Derry, N. H., were sprayed with a mixture of lead arsenate and

water in the proportion of 5 pounds of arsenate to 100 gallons of water, fish oil being added as an adhesive. The infestation on these trees was at the time medium to heavy, and they were defoliated 15 to 20 per cent. A single poplar near by was left as a check. On

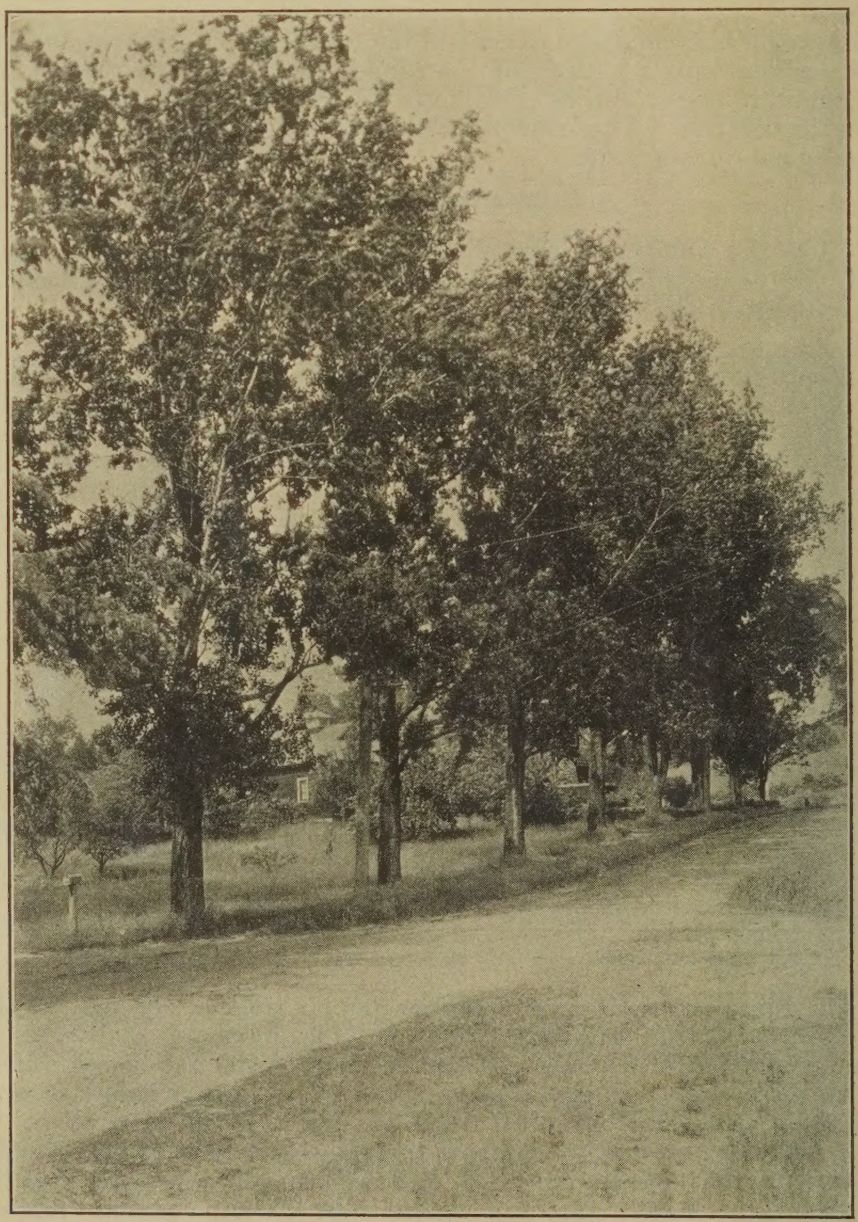

FIGURE 2.—Carolina poplar trees at Nashua, N. H., sprayed June 8, 1928, with a mixture of powdered lead arsenate, water, and fish oil. Photographed June 12, 1929

the same date two small blocks of balm-of-Gilead trees at Ipswich, Mass., were sprayed with a mixture of the same composition, including fish oil as an adhesive. Infestation here was likewise medium to heavy. Some of the trees were defoliated 20 per cent, others as

high as 50 per cent. A few balm-of-Gilead trees near by were taken as a check.

On June 26 five Carolina poplars of medium to large size at Topsfield, Mass., were sprayed with a similar mixture, in the proportion of 3 pounds of powdered lead arsenate to 100 gallons of water, with the usual addition of fish oil. The infestation on these trees was medium, and they were defoliated 10 to 15 per cent. A Carolina poplar near by was left as a check.

In all of these experiments fish oil was added to the spray in the proportion of 4 ounces of it to each pound of powdered lead arsenate.

OBSERVATIONS AT THE END OF THE FEEDING SEASON OF 1928

On July 19 and 20, 1928, these trees were examined. The increase in defoliation of the sprayed trees in the different localities averaged

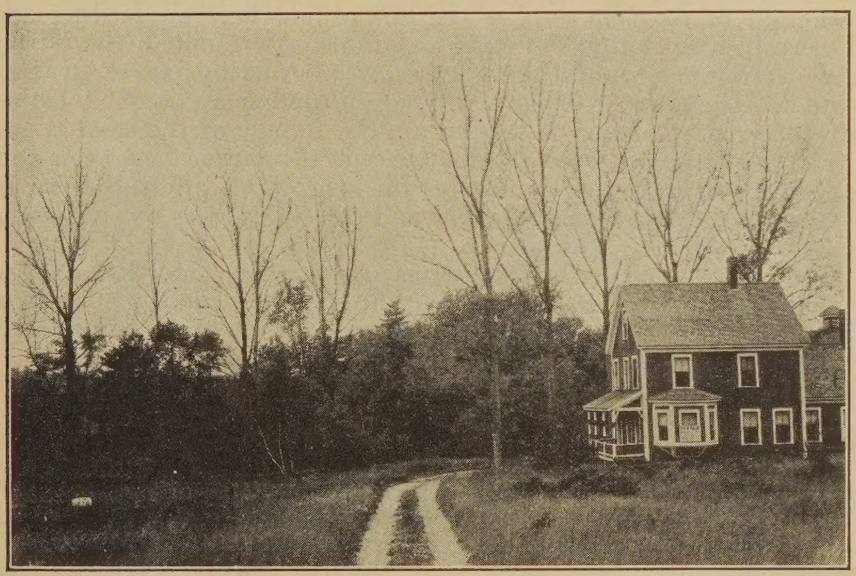

FIGURE 3.—Large Carolina poplar trees at Nashua, N. H., used as checks on similar trees sprayed June 8, 1928, when the latter and the check trees had been defoliated about 15 per cent. About 12 days later the check trees had been defoliated 90 to 100 per cent, whereas the increase in defoliation of the sprayed trees averaged 2 to 5 per cent. Photographed June 30, 1928

from 2 to 5 per cent. The check trees at Nashua, N. H., were defoliated 90 to 100 per cent. (Fig. 3.) The single check tree at Derry, N. H., was defoliated 30 to 40 per cent, and one located in another section of the same town was defoliated 35 to 40 per cent. At Ipswich, Mass., the check trees were defoliated 70 to 80 per cent; the one at Topsfield, Mass., was defoliated 75 to 85 per cent.

In all of the experiments conducted in 1928 the spraying controlled the satin moth very effectively. At the time of pupation the spray was still conspicuous on much of the foliage. An attempt was then made to determine whether the spray remaining on the foliage would control the larvae of the first and second stages of the next generation. Some of both the sprayed trees and the check trees were examined to determine the degree of reinfestation. If the infestation on the different trees was not sufficiently heavy, the number of egg clus-

ters on them was increased to a point where infestation of medium to great severity would be brought about—100 to 200 egg clusters per tree, depending upon the size of the tree.

As a rule the larvae of the satin moth hibernate in the crevices of the bark, but it was found that burlap bands placed around the trees afforded an excellent cache in which many of the larvae constructed their webs for hibernation. A strip of burlap 8 inches wide was used in these experiments, a band of it being held to the tree by heavy twine placed at the middle, after which the upper half of burlap was turned down over the twine.

In view of this fact one to three burlap bands were placed around some of the sprayed trees and some of the check trees. If three burlap bands were used, the lower one was placed from 4 to 5 feet from the ground, the middle one 10 to 15 feet, and the upper one 20 to 25 feet, the exact placing distance in each case depending somewhat on the height of the tree. After the larvae had finished feeding and all were in hibernation the extent of feeding was noted, the burlap bands were removed, and the number of hibernating larvae on them counted. The number of larvae found on the burlap bands, together with the relative extent of feeding on the foliage of the treated and untreated trees, indicated to what extent the larvae had been controlled by the spraying, and also the degree of infestation to be expected on both the sprayed trees and the check trees the following season.

Table 1 presents various data relating to the proportion of lead arsenate used in the spray, the date of application, and the number of larvae per square foot of burlap found hibernating on the bands.

TABLE 1.—*Data on experiments in spraying trees in 1928 for control of the satin moth*

Tree No.	Location	Date sprayed	Lead arsenate per 100 gallons of water[1]	Larvae found on burlap	Area of burlap	Larvae found per square foot
			Pounds	*Number*	*Square feet*	*Number*
1	Derry, N. H.	June 8	5	2	4.4	1
Check	do			343	3.2	107
1	Nashua, N. H.	June 8	5	13	12.1	1
2	do	do	5	0	11.0	0
3	do	do	5	0	4.0	0
Check	do			67	14.1	5
1	Derry, N. H.	June 15	5	30	7.8	4
2	do	do	5	2	4.5	1
Check	do			1,924	10.6	181
1	Ipswich, Mass.	June 15	5	0	1.3	0
2	do	do	5	0	2.0	0
Check	do			270	1.0	270
Do	do			288	.6	480
1	Topsfield, Mass.	June 26	3	0	5.3	0
2	do	do	3	0	2.6	0
Check	do			1,335	5.5	243

[1] Fish oil was added to the spray mixtures in the proportion of 4 ounces to each pound of lead arsenate.

The average number of hibernating larvae per square foot of burlap was considerably less on the sprayed than on the unsprayed, or check, trees. The total area of burlap on the 10 sprayed trees was 55 square feet, and on the 6 check trees 35 square feet. The aver-

age number of larvae per square foot of burlap on the sprayed trees was 1 or less, and on the check trees the average per square foot was 121. The feeding on the check trees by the small larvae of the satin moth in July and August was very noticeable, while on the sprayed trees, though little poison was noticeable on some of the foliage, no feeding was seen except to a very small extent on some of the new growth.

From the time of the first application of spray in the feeding season of the first generation in 1928 to the end of the feeding period of the small larvae of the succeeding generation in the same year, the total rainfall was 9.74 inches.

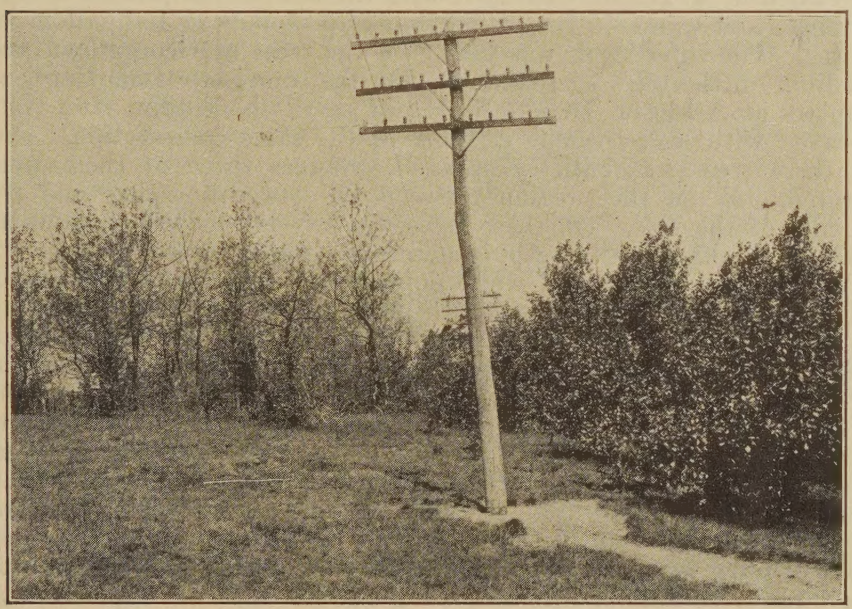

FIGURE 4.—Balm-of-Gilead trees experimented with in 1928, those at the right of the telephone line being sprayed in that year, and those at the left not sprayed. None of these trees was sprayed in 1929. Photographed in June, 1929

CONDITION OF TREES IN 1929

From these observations and results it was inferred that the infestation on the sprayed trees during the summer of 1929 would be very light, with little or no feeding taking place, but that on the check trees the feeding would be more or less heavy.

During the summer of 1929 observations were made on all of the poplar trees sprayed in 1928, and they were found to be in excellent condition, with little or no feeding observed on them, the one application having controlled the satin moth for two years. On the check trees much feeding was found, some of the trees being defoliated 75 to 100 per cent. In Ipswich, Mass., the balm-of-Gilead trees sprayed in 1928 were in perfect condition in 1929, whereas the trees in the same locality which were not sprayed in 1928 were almost entirely defoliated in 1929. (Fig. 4.)

EXPERIMENTS IN 1929[3]

The experiments conducted in 1929 were along somewhat the same lines as those conducted in 1928. Poplar trees, moderately to heavily infested with the satin moth, were selected in Salem, Plaistow, and Atkinson Depot, N. H., and in Georgetown and Topsfield, Mass.

The spray operations in 1929 were begun somewhat earlier in the season than those conducted in 1928, the applications being made on three different dates, May 27, June 6, and June 10. Fish oil was used as an adhesive in all of the spray mixtures, in the proportion of 4 ounces to each pound of lead arsenate. On May 27 two balm-of-Gilead trees at Georgetown, Mass., and three Carolina poplars at Plaistow, N. H., were sprayed with the mixture of powdered lead arsenate and water, in the proportion of 5 pounds to 100 gallons of water. The infestation was heavy on the trees at Georgetown and medium on the trees at Plaistow. On the same date four Carolina poplars at Atkinson Depot, N. H., of small to medium size, were sprayed with lead-arsenate mixture of the same composition. One of these trees was entirely sprayed, whereas three of them were treated only on the portion between the lower branches and the middle of the tree. On these trees the infestation was medium to heavy. Another tree near by was selected for a check.

As Carolina poplar and white poplar trees often grow to a height of 50 to 60 feet, it is difficult, with much of the spraying equipment in common use, to reach the upper part of them. It was for this reason that some of the trees were sprayed on the lower half to ascertain how much control would be obtained when such technic is used.

On June 6 seven Carolina poplars in Salem, N. H., of medium to large size were sprayed with the mixture of powdered lead arsenate and water in the same proportion as before. These trees were at this time defoliated 10 to 15 per cent, the infestation being medium. On the same date four Carolina poplars, medium to large, in another part of town were sprayed with the same mixture. These trees were moderately to heavily infested, being defoliated 20 to 40 per cent at the time of spraying. The check trees selected for these experiments were near by, and were rather heavily infested. On the same date three Carolina poplars at Topsfield, Mass., were sprayed with the mixture of powdered lead arsenate and water, this time in the proportion of 4 pounds to 100 gallons of water. The infestation was of medium extent, and the trees were defoliated 10 to 15 per cent.

On June 10, 11 Carolina poplars, at Salem, N. H., were sprayed with the usual mixture in the proportion of 5 pounds of lead arsenate to 100 gallons of water. The infestation on these trees was medium to heavy, and they were defoliated 15 per cent at the time of the spraying. The check trees near by were also moderately to heavily infested.

OBSERVATIONS AT THE END OF THE FEEDING SEASON OF 1929

On July 15, observations were made of all of the sprayed trees and the check trees. The increase in defoliation on all of the sprayed trees averaged about 5 per cent, with the exception of the three trees at Atkinson Depot, N. H., which were sprayed on the lower half, these

[3] Power equipment for spraying used in these experiments in 1929 was lent by A. F. Burgess, in charge of moth work, Plant Quarantine and Control Administration, U. S. Department of Agriculture.

showing an increase of 30 to 35 per cent in defoliation on the upper half of the tree, or an average of 15 to 20 per cent for the entire tree.

The spray had controlled the satin moth efficiently on all of the fully sprayed trees; on those of which only the lower half was sprayed little feeding was observed below, but the upper, or unsprayed, portion was defoliated about 40 per cent and appeared ragged; the defoliation of the tree as a whole was 20 to 25 per cent.

The check tree at Georgetown, Mass., was defoliated about 35 per cent. It had been sprayed at about the middle of the season without the writer's knowledge by either the town authorities or a private concern, with the result that the percentage of defoliation was considerably reduced.

Of the check trees in the New Hampshire towns the one at Atkinson Depot was defoliated 75 to 80 per cent, that at Plaistow 65 per cent, and those at Salem 60 to 95 per cent. The check tree at Topsfield, Mass., was defoliated 75 to 80 per cent.

In July the number of new clusters of eggs of the satin moth on both the sprayed trees and the check trees was ascertained. If the number was sufficient to give what would be considered an infestation medium to heavy in severity, no clusters were added; if not, the number was increased, with the idea of making the infestation as uniform as possible on all of the trees. After the eggs in the clusters were completely hatched burlap bands were placed on a number of both the sprayed and the check trees, as was done in the series of experiments of 1928. After the larvae had left the foliage the extent of feeding on the sprayed trees and the check trees was noted, the burlap bands removed, and the number of hibernating larvae on them recorded. On the trees that were fully sprayed, the feeding by the young larvae was restricted to the new foliage; in the case of the trees sprayed on the lower half the feeding was quite noticeable on the unsprayed portion of the trees, while considerable feeding was found on all of the check trees. Table 2 presents various data relating to the proportion of lead arsenate used in the spray, the date of application, and the number of larvae per square foot of burlap found hibernating on the bands.

TABLE 2.—*Data on experiments in spraying trees in 1929 for control of the satin moth*

Tree No.	Location	Date sprayed	Lead arsenate per 100 gallons of water [1]	Larvae found on burlap	Area of burlap	Larvae found per square foot of burlap
			Pounds	*Number*	*Square feet*	*Number*
1	Atkinson Depot, N. H.	May 27	5	56	4.3	13
2 [2]	do	do	5	367	6.4	57
3 [2]	do	do	5	690	5.1	135
Check	do			800	3.4	235
4	Plaistow, N. H.	May 27	5	250	9.1	29
Check	do			4,967	8.4	591
5	Georgetown, Mass.	May 27	5	120	12.0	10
6	Salem, N. H.	June 6	5	201	9.0	22
7	do	do	5	35	6.8	5
Check	do			892	2.0	446
8	Topsfield, Mass.	June 6	4	350	9.5	37
Check	do			3,277	7.4	443
9	Salem, N. H.	June 10	5	17	7.9	2
10	do	do	5	8	5.2	2
11	do	do	5	8	4.0	2
Check	do			6,847	7.3	937

[1] Fish oil was added to the spray mixtures in the proportion of 4 ounces to each pound of lead arsenate in the tank.

[2] Lower half of each tree sprayed.

It may be seen from Table 2 that the number of hibernating larvae per square foot of burlap on the fully sprayed trees was very small, on the trees sprayed on the lower half somewhat larger, and on the check trees still larger. The total area of burlap on the 9 fully sprayed trees was 67.8 square feet, and the average number of hibernating larvae per square foot of burlap was 15.4. On the 2 trees sprayed on the lower half, the total area of burlap was 11.5 square feet, and the average number of hibernating larvae per square foot was 92, while the 5 check trees, on which was 28.5 square feet of burlap, showed an average of 589 hibernating larvae per square foot.

The trees last mentioned are to be considered heavily infested, in view of certain experiments conducted in 1928, when 14 unsprayed trees known to be heavily infested showed a count of 457 larvae per square foot of burlap.

From the time of the first application of spray in the feeding season of the first generation in 1929 to the end of the feeding period of the small larvae of the succeeding generation in the same year a total of 4.46 inches of rain fell.

The experiments in 1929 gave about the same results as those conducted in 1928. The fully sprayed trees, judging from the small number of hibernating larvae found on the burlap bands, were very lightly infested, and only minimum feeding was to be expected on the foliage in the following season. In the case of trees sprayed on the lower half, the number of larvae found on the burlap bands indicated that light feeding on the foliage was to be expected the next season, whereas the check trees, on which an average of 589 hibernating larvae per square foot of burlap was found, should in that season show considerable defoliation.

The number of hibernating larvae per square foot of burlap on the sprayed trees in 1929 was considerably larger than that recorded in 1928; this increase, however, was undoubtedly due to the spraying having been done earlier in 1929 than in 1928. Because of this fact a much larger quantity of new unsprayed foliage was present in 1929 on the trees sprayed at the time when the young larvae were feeding. Some of these larvae were therefore able to feed during the period preceding hibernation without coming in contact with the sprayed foliage. The number of larvae, however, which escaped the poisoned foliage was very small as compared with the number of hibernating larvae on the check trees.

CONDITION OF TREES IN 1930

In the spring and early summer of 1930 the poplar trees sprayed in 1929 were examined; on those which had been fully treated the infestation was very light, whereas on the three trees at Atkinson Depot which had been only half sprayed the infestation was light to medium; on the check or untreated trees there were many larvae, and much feeding was observed.

RESULTS OF EXPERIMENTS OF 1928 AND 1929

The outstanding results of these experiments were the excellent control of the larvae of the satin moth during May and June and the high mortality of the small larvae of the next generation in July

and August—both brought about by one spraying with lead arsenate to which fish oil had been added as an adhesive. Owing to the high mortality, the number of overwintering larvae on the sprayed trees was very small. The infestation on the trees sprayed in 1928 was very light in 1929, and the infestation on the trees fully sprayed in 1929 was very light in 1930, as has been observed. No spraying was necessary in 1929 on the trees sprayed in 1928, nor was it necessary in 1930 to spray those sprayed in 1929, except the ones sprayed on the lower half only.

USE OF FISH OIL

Fish oil should be added to the spray mixtures in the proportion of 4 ounces to 1 pound of lead arsenate powder or insoluble matter used; that is, if 5 pounds of the poison is used to 100 gallons of water, 20 ounces, or about 1¼ pints, of fish oil is required. One quart of fish oil weighs approximately 31 ounces. If fish oil is not available, the same quantity of raw linseed oil may be substituted. In using fish oil as an adhesive the best results in the writers' experience were obtained by pouring the oil into the spray tank after the lead arsenate had been well mixed with the water and while the mixture was being agitated. The best grade of fish oil should always be used; it is known as light-pressed fish oil, and is yellow to brown in color. A cheaper grade, known as crude fish oil, can be obtained, but as it contains stearin it is likely to clot, and in the long run its use is not economical.

CONCLUSIONS

The experiments described herein show clearly that the satin moth can be satisfactorily controlled for two years by one application of a mixture of lead arsenate powder and water in the proportion of 5 pounds of the arsenate to 100 gallons of water, with fish oil added as an adhesive. This is the first time, to the writers' knowledge, that an insect has been successfully controlled for two seasons by one application of lead arsenate. If some of the trees are very tall, and only one-half to two-thirds of the foliage can be treated by the spray equipment available, fairly good control can be obtained by this procedure, but under such conditions it will be necessary to spray every year, as the hibernating larvae on the trees will probably be sufficiently numerous to cause more than negligible injury to the foliage in the following season.

The length of time that a lead-arsenate spray remains on the foliage is extended considerably by the use of fish oil. The larger larvae of one generation and the young larvae of the next generation are therefore satisfactorily controlled, provided the spraying is thoroughly done. The fact that the young larvae feed on both surfaces of the foliage present at the time of spraying, as well as on the newer growth which comes later, makes the conditions favorable for good control. The infestation on the trees in the following season will therefore be very light or almost negligible, and no spraying will be necessary unless there is a migration of larvae from heavily infested trees near by. It follows that ordinarily it will not be necessary to spray more often than every two years, and that in some sections or localities where reinfestation does not occur during that

period the spraying operations can be postponed for a still longer time. A preliminary examination of the foliage taken late in the summer of the second year in order to observe the extent of the feeding thereon by the small larvae should indicate whether treatment is again necessary on all of the trees, or only on those in certain locations.

The spraying operations in a town or city could be so arranged that either a part of the area could be treated in one year and the remainder in the following year, or the entire area sprayed every second year. The preliminary examination of the foliage late in the summer in which the spraying was done may indicate, however, that not all of the trees in the section will require treatment the next season. Sometimes, therefore, it may be that parts of the area may not need a spraying as often as every other year.

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